

Optimization of Stress-Induced Transformation in Zirconia-Toughened Alumina

H.S. Shulman, *Ceralink, Inc., Alfred, NY*

W.J. Walker Jr., *NYS College of Ceramics at Alfred University, Alfred, NY*



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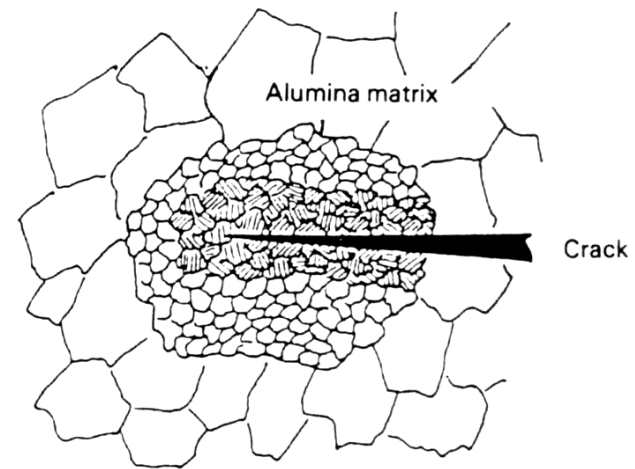
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Ceralink

Background -- ZTA

† ZTA - Zirconia-Toughened Alumina

- † Zirconia grains in an alumina matrix
- † Transformation toughening mechanism



 Y-PSZ agglomerate (t-ZrO₂)


 Transformed Y-PSZ (monoclinic)

Fig 12 Schematic of the toughening mechanism in a duplex-toughened ceramic using agglomerated zirconia particles

Image from Stevens, in ASM Handbook, p779

Background -- ZTA

- † Transformation Toughening
 - † Metastable tetragonal grains transform to monoclinic
 - † Absorbs fracture energy
 - † Volume increase opposes crack growth
 - † Increases strength and toughness

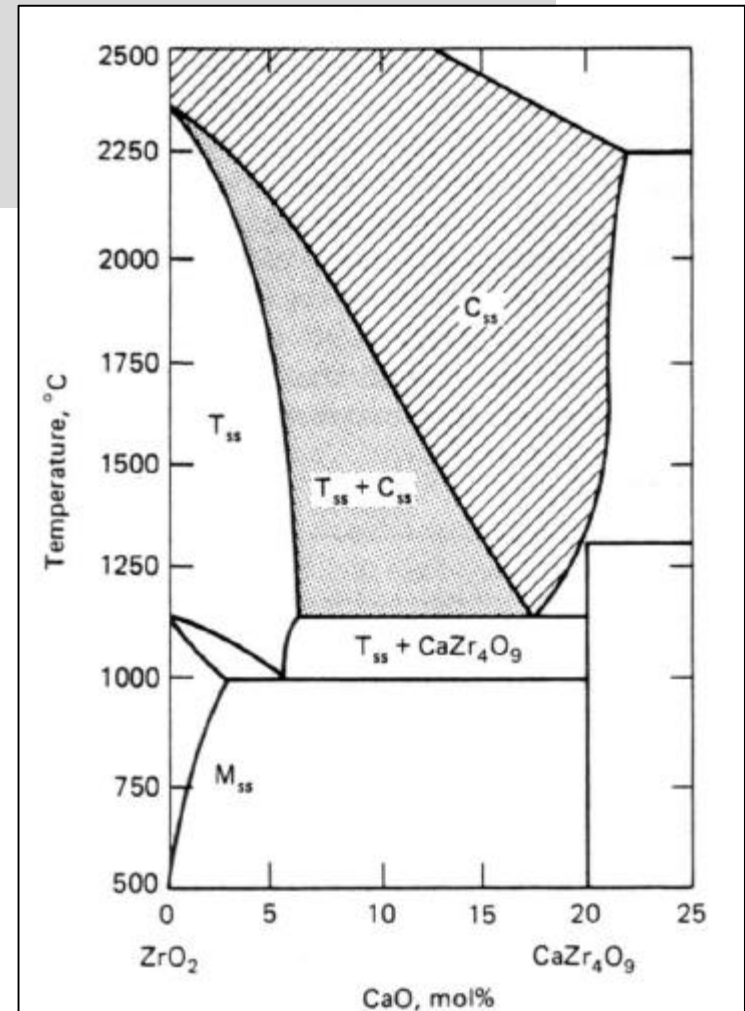
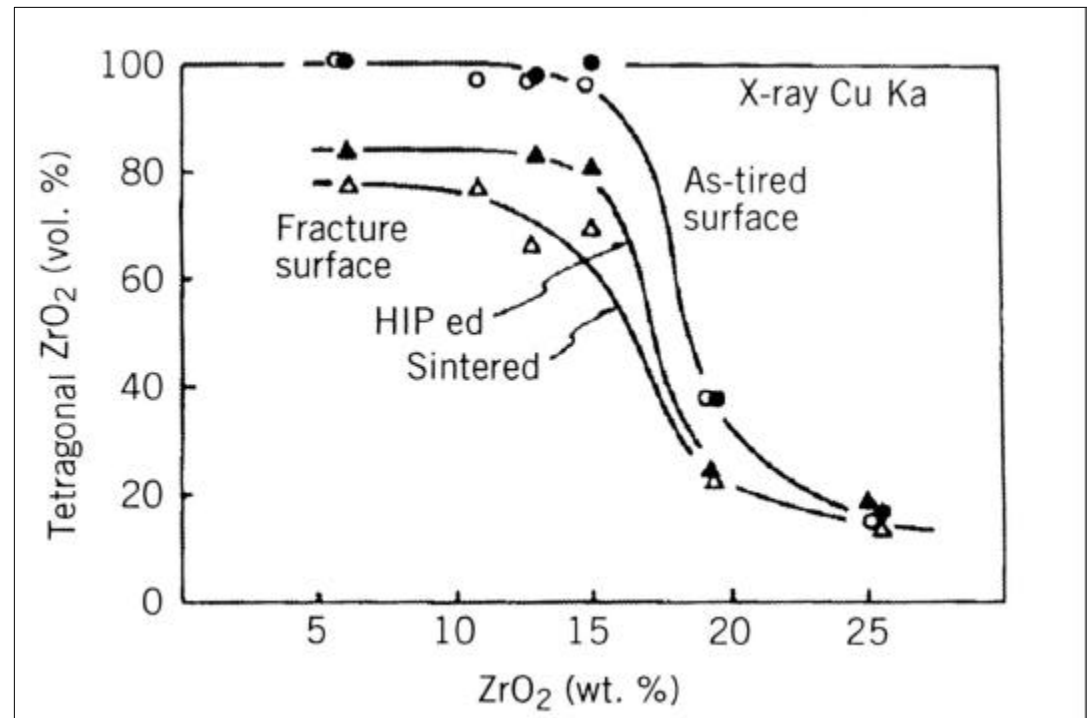


Fig 1 Part of the equilibrium phase diagram for the system ZrO₂-CaO. C_{ss} refers to the cubic solid-solution phase, T_{ss} to the tetragonal solid-solution phase, and M_{ss} to the monoclinic solid-solution phase. Source: Ref 3

Background -ZTA

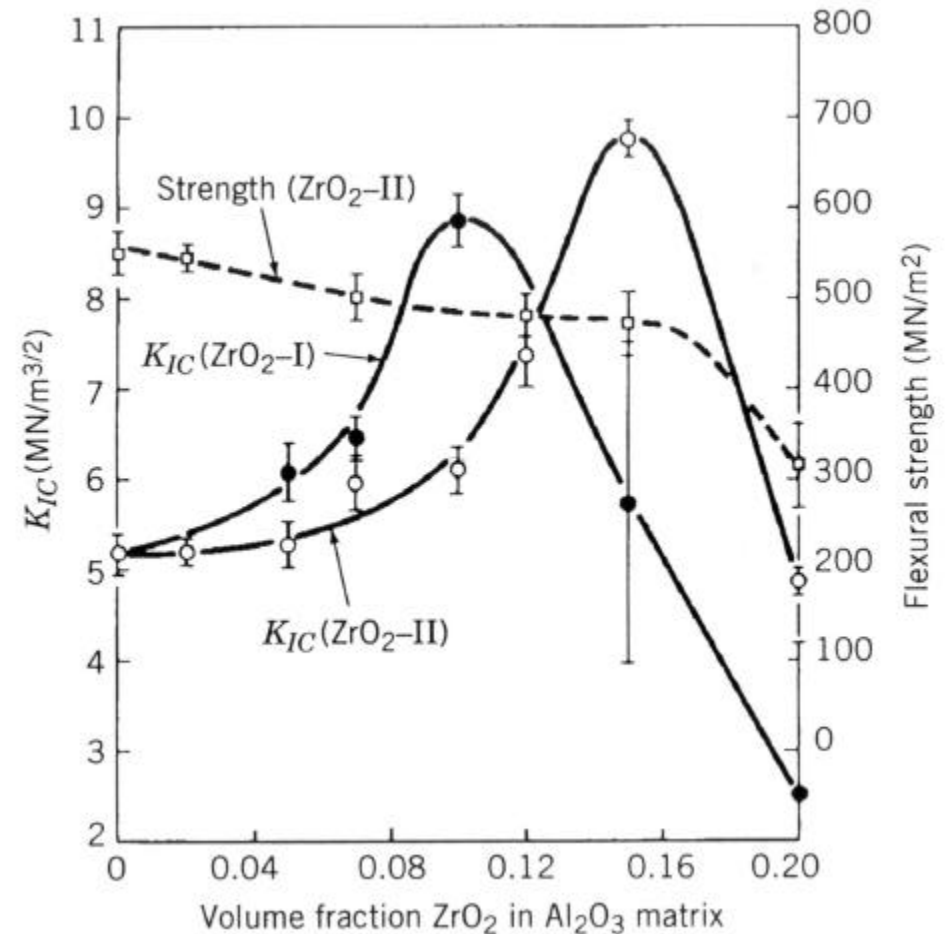
† Influence of ZrO₂ content in ZTA

- † ZrO₂ grains constrained by alumina matrix
- † Tetragonal up to ~15 vol% ZrO₂
- † Monoclinic above ~15 vol%
- † (no additives in ZrO₂)



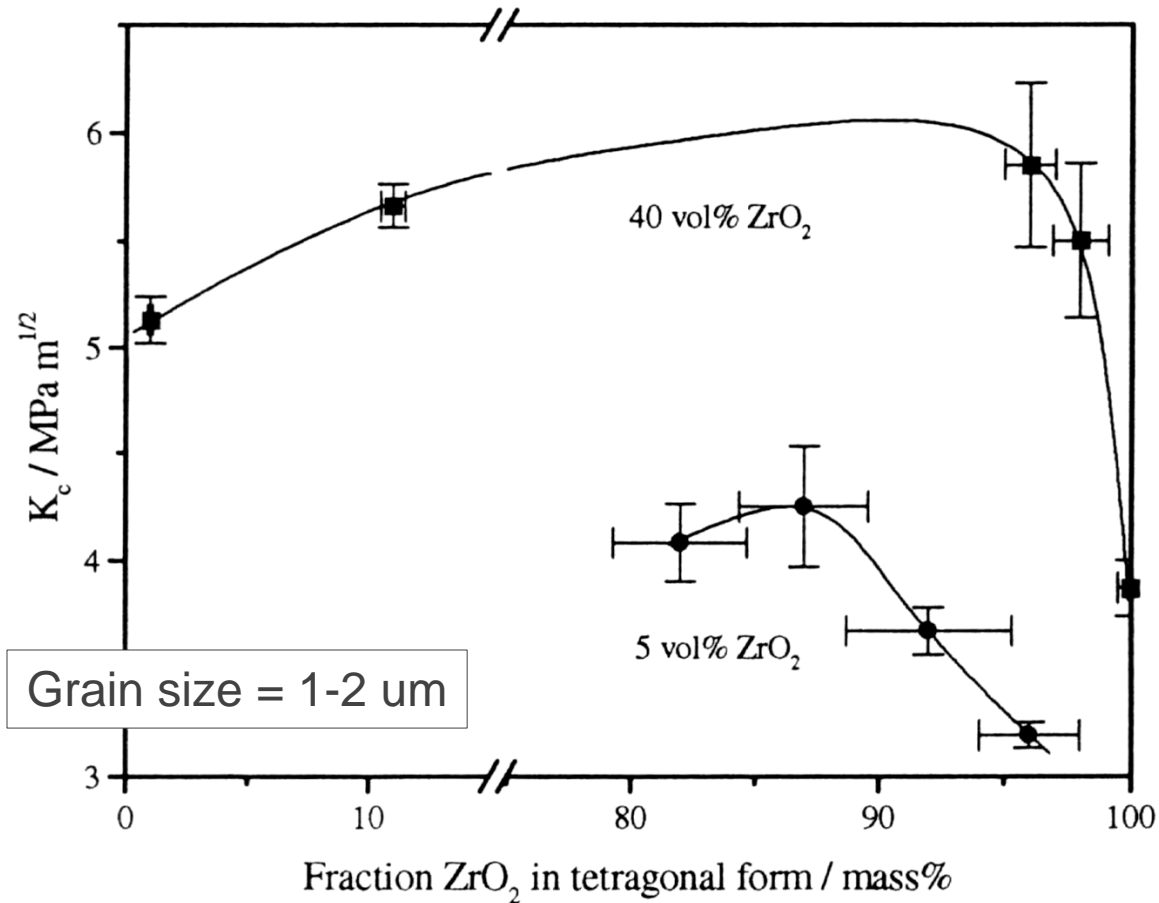
Background - ZTA

- † Maximum Fracture Toughness
 - † ZrO_2 content
 - † Grain size
 - † Depends on t- ZrO_2
- † Stabilizing t- ZrO_2 by adding Y_2O_3 allows higher ZrO_2 content



Previous Results

Shulman et al, *J. Australasian Ceram. Soc.*, 34 [2] 127 (1998)



Objectives

- † Maximize Fracture Toughness and Hardness of ZTA
- † Determine the optimum level of stabilization of ZrO_2 in ZTA by Y_2O_3 addition

Experimental Procedure

Sample Preparation

† ZTA --

- † 40 vol% ZrO₂ (Tosoh)
 - † Y₂O₃ = 0 to 3 mol%
- † 60 vol% Alumina (Alcoa A-16SG)

† Hardness and Fracture Toughness

- † Indentation method

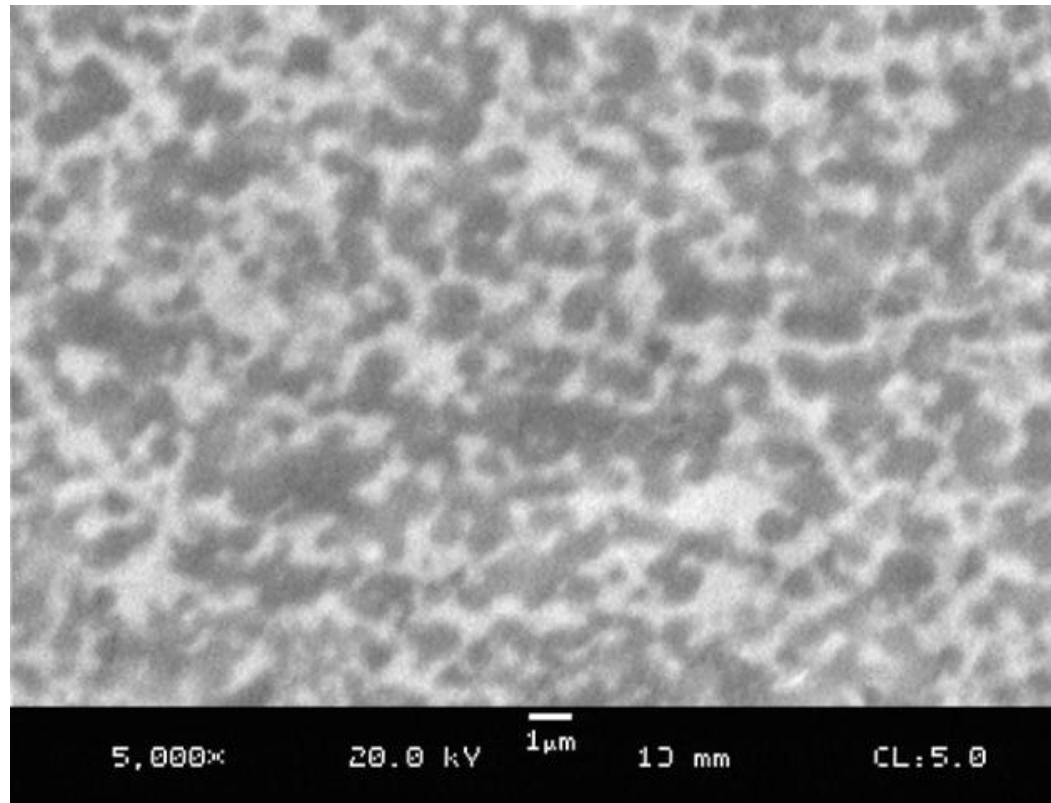
† Phase content by X-ray diffraction

Sample Preparation

- † Aqueous slurries
 - † 35 vol% solids
 - † 0.75% Darvan 821A
 - † 3% PEG-8000
 - † Milled for 24 hours
- † Dried at 100 C
- † Crushed with mortar & pestle
 - † Sieved
- † Die Pressed to 50 MPa
- † CIPed to 140 MPa
- † Sintered in air to 1540 C with 3 hour soak
- † Polished to 6 μm (diamond)

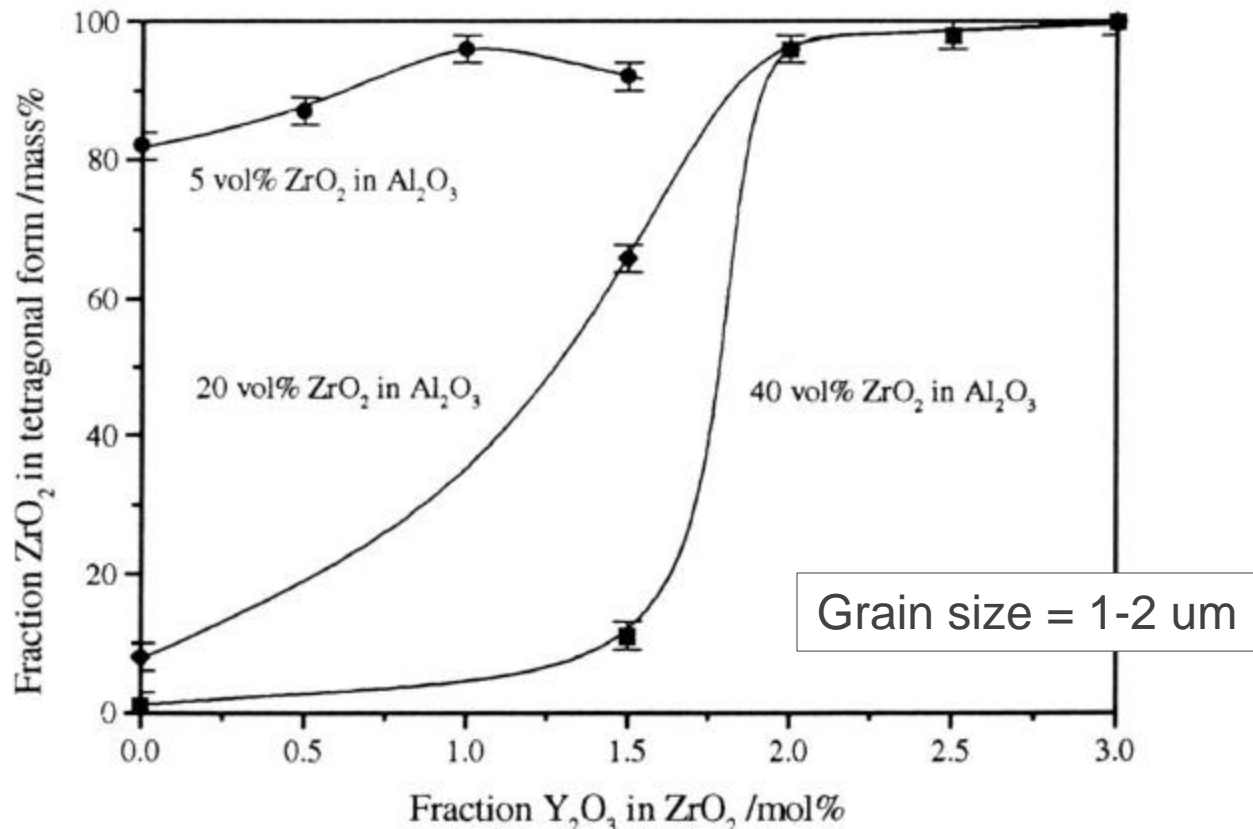
Microstructure

† Grain size $\sim 1 \mu\text{m}$



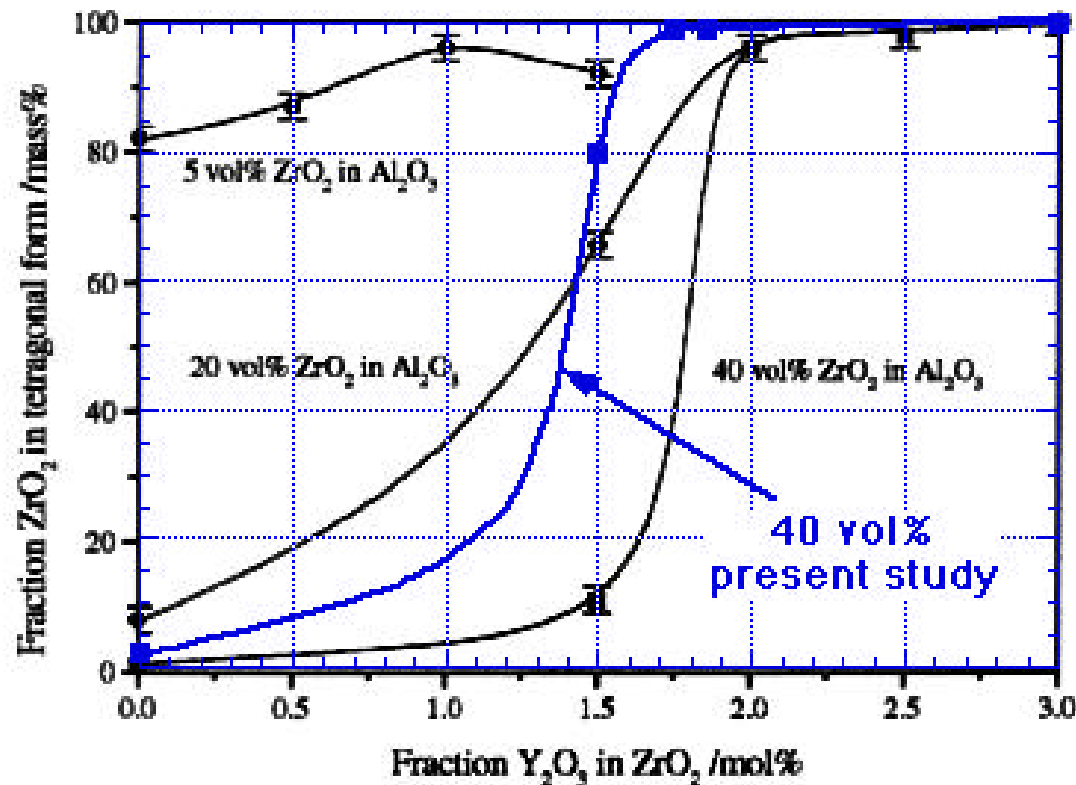
Previous Results

† Influence of Y_2O_3 addition on phase content



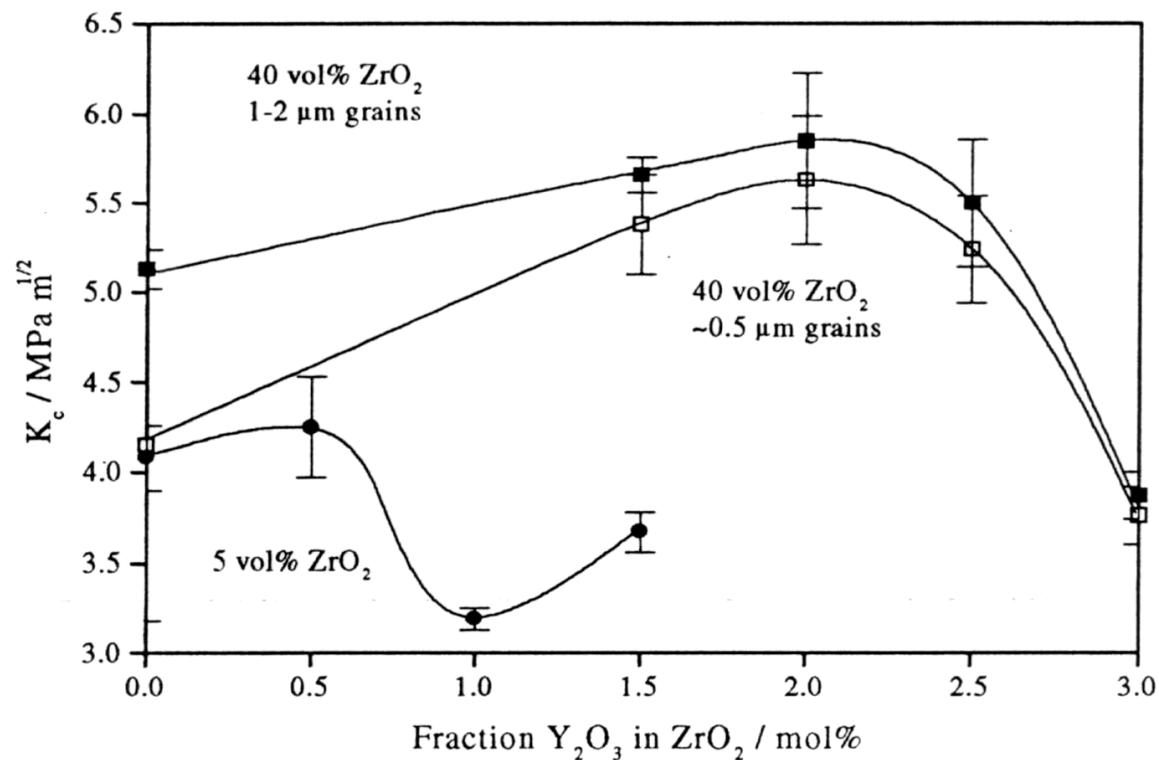
Present Work

† Influence of Y_2O_3 addition on phase content



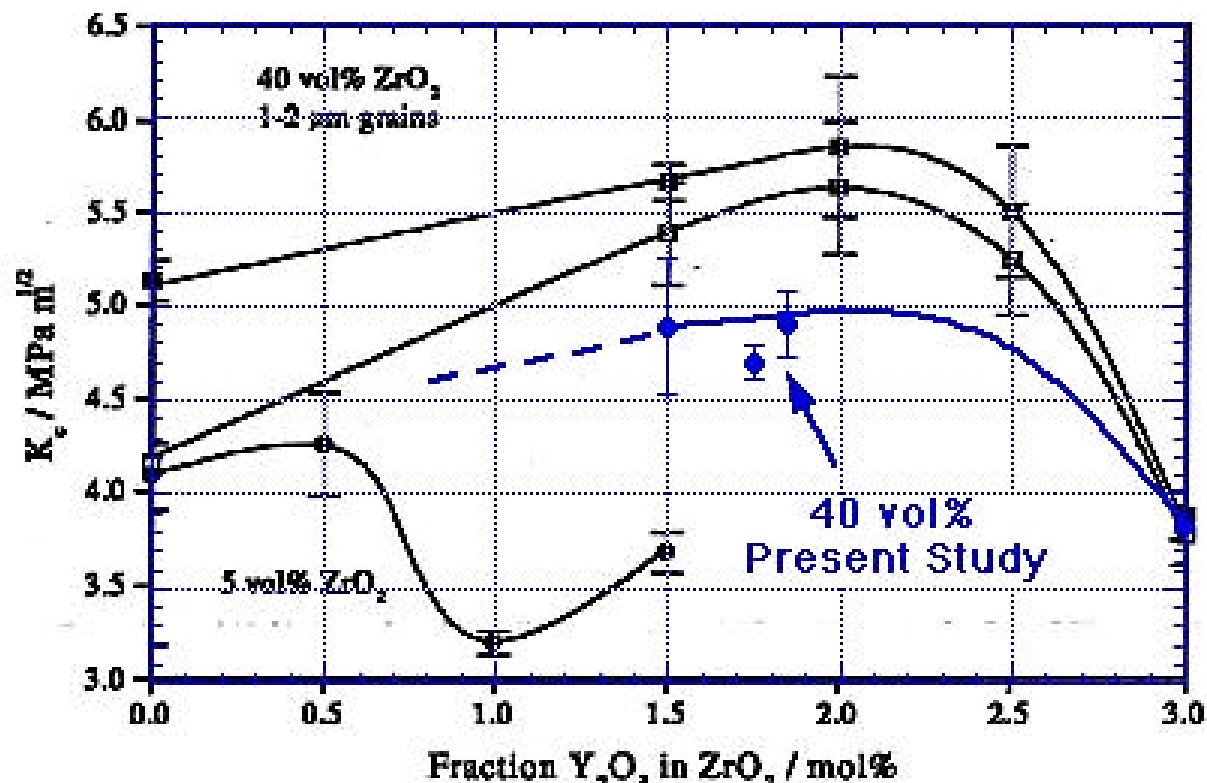
Previous Results

† Fracture Toughness



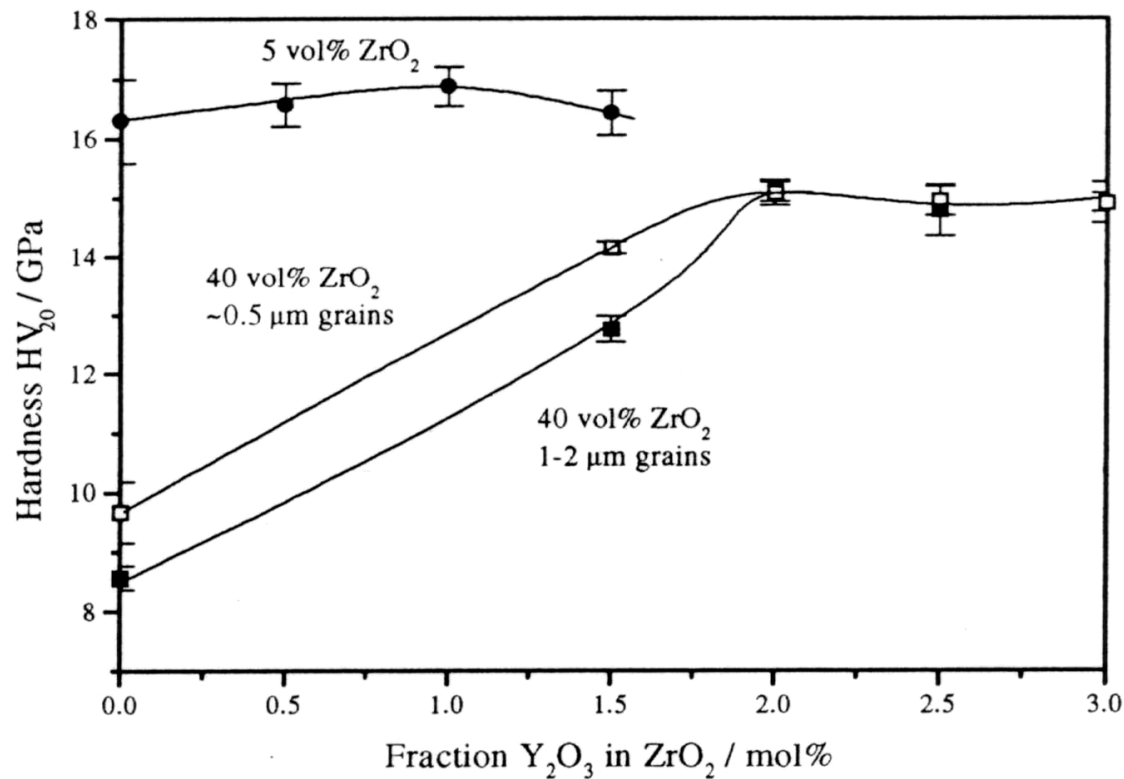
Present Work

† Fracture Toughness



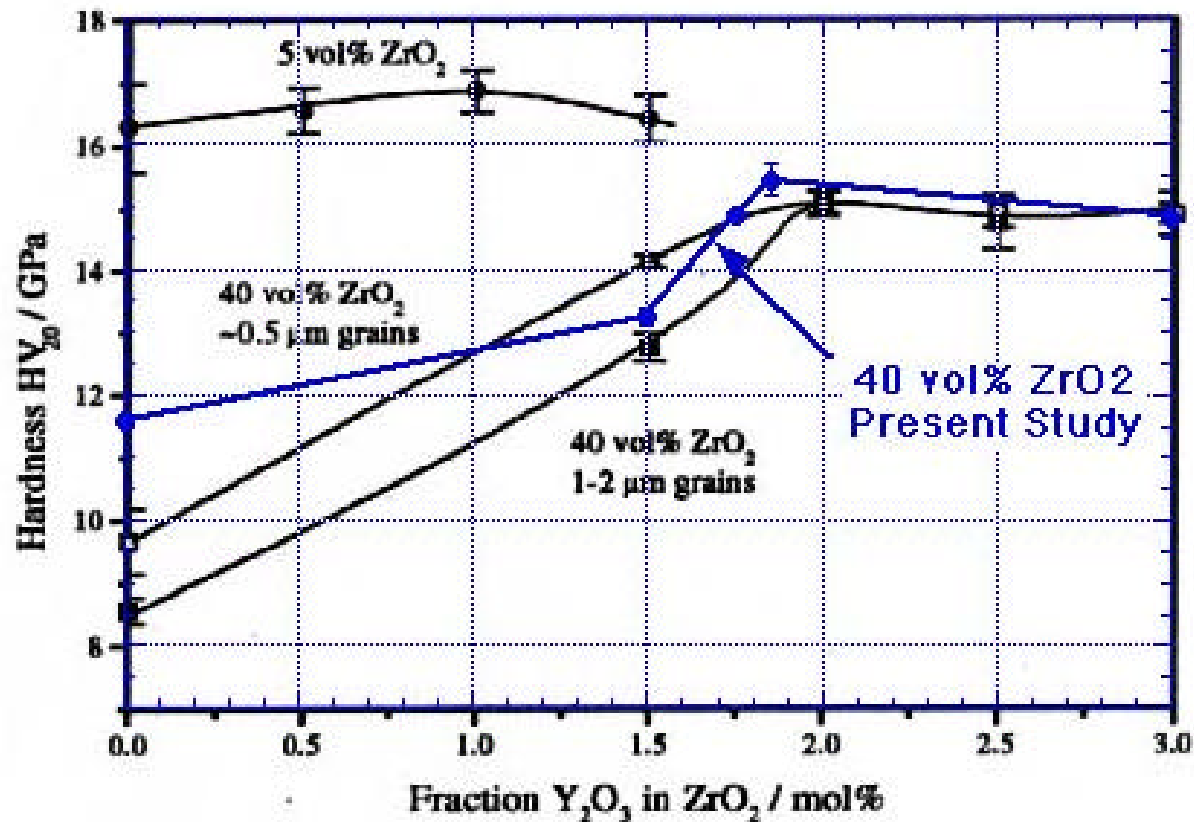
Previous Results

† Hardness

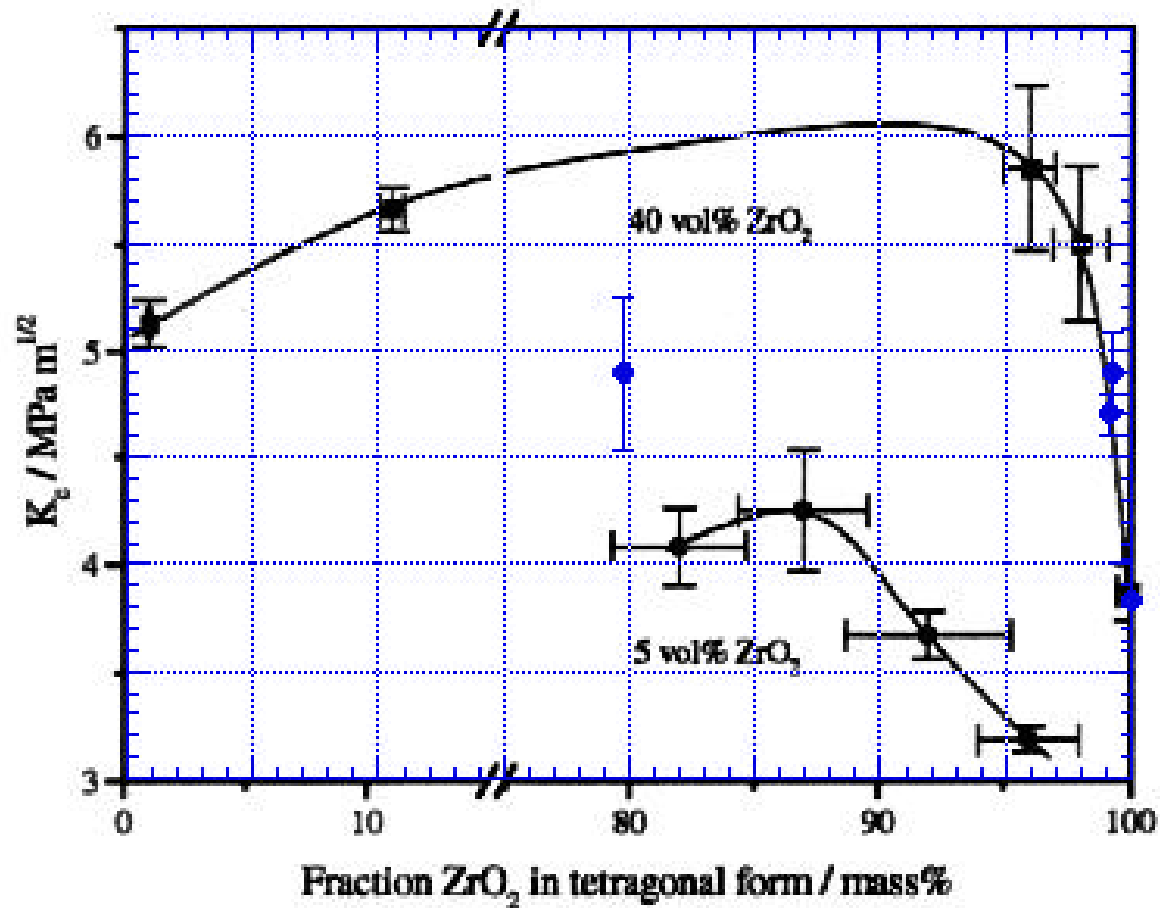


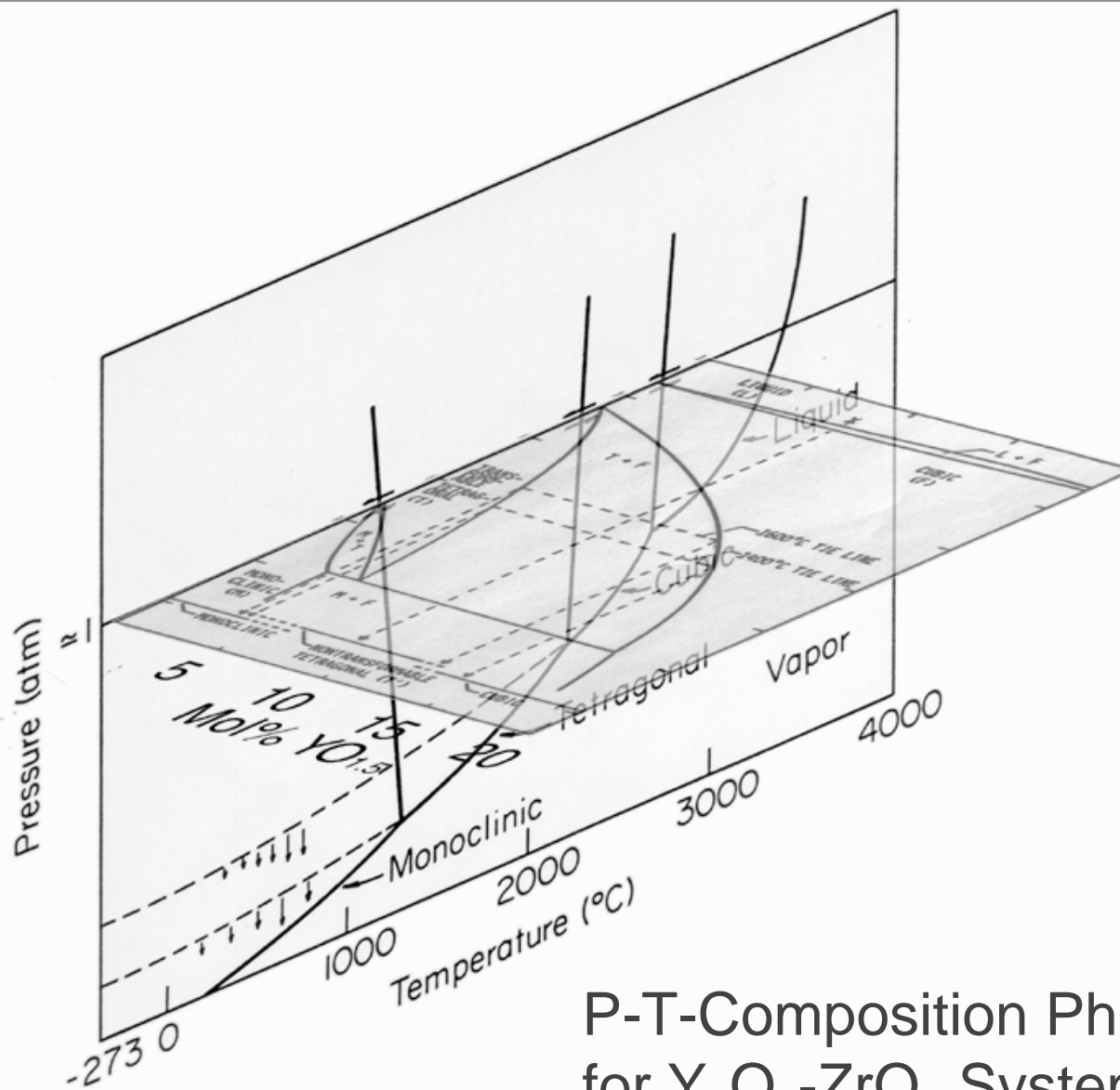
Present Work

† Hardness



Present Work



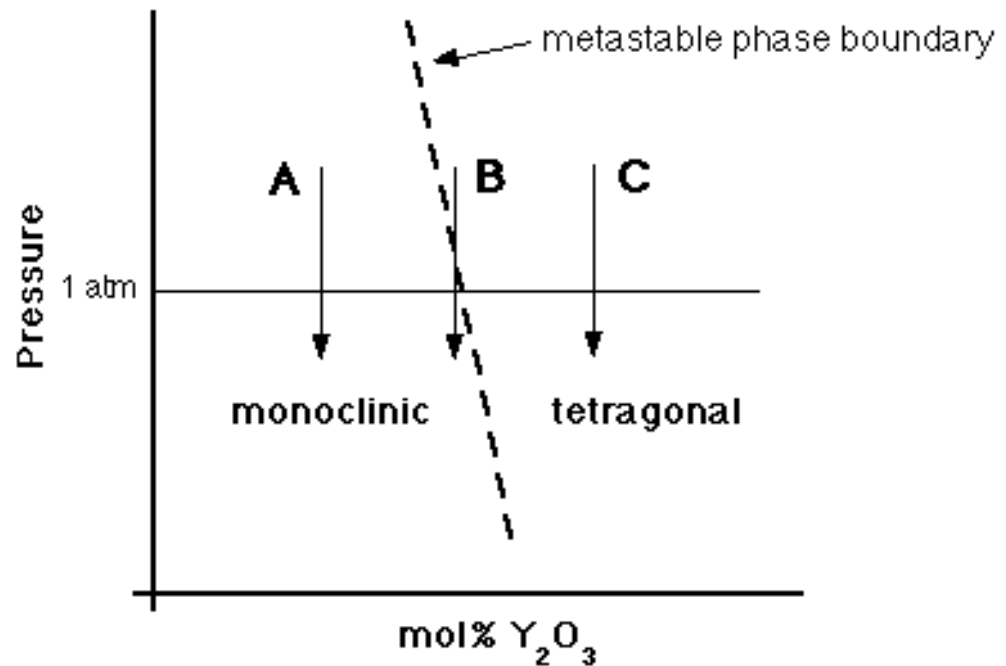


P-T-Composition Phase Diagram for Y_2O_3 - ZrO_2 System

Discussion

- † Alumina matrix constrains ZrO_2 grains (applies Pressure)
- † Fracture relieves pressure

A = understabilized
B = transformable
C = overstabilized



Proposed Pressure vs Composition Phase Diagram for Y_2O_3 - ZrO_2

Summary

- † Y_2O_3 level in ZTA controls the ZrO_2 phase composition ($m\text{-ZrO}_2$ vs $t\text{-ZrO}_2$)
- † Maximum Fracture Toughness of ZTA occurs near the metastable $m\text{-ZrO}_2/t\text{-ZrO}_2$ phase boundary
- † Hardness similar to Al_2O_3 can be achieved in ZTA

Future Work

- † Determine optimum ZTA composition
 - † Y_2O_3 level
 - † Grain size
 - † Al_2O_3/ZrO_2 ratio
- † Thermodynamic modeling
- † Micro/millimeter wave processing